

Learning About Photovoltaic Systems



RENEWABLE ENERGY
THE INFINITE POWER
OF TEXAS

HIGHLIGHTS

- The energy needs of a typical home in Texas could be met by covering only half of its roof with solar electric panels
- Photovoltaic (PV) cells convert sunlight directly into electricity without creating any air or water pollution

way. Home photovoltaic systems are comprised of photovoltaic cells, devices that convert light energy directly into electricity, and inverters that convert the direct current from the photovoltaic into alternating current used in homes. Because the source of light is usually the sun, they are often called solar cells. The word photovoltaic comes from “photo,” meaning light, and “voltaic,” which refers to producing electricity. Therefore, the photovoltaic process is “producing electricity directly from sunlight.” Photovoltaics are often referred to as PV.

Texans who already have electrical grid-supplied electricity but want to begin to live more independently or who are concerned about the environment are installing PV systems. For some applications where small amounts of electricity are

INTRODUCTION

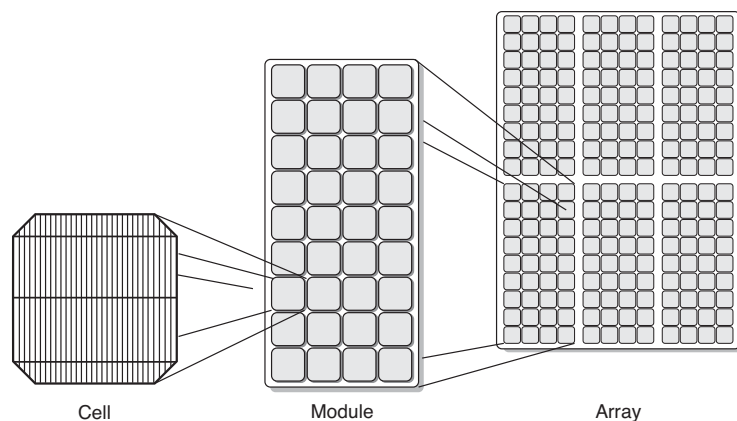
Solar energy can be part of a mixture of clean, renewable energy sources used to meet Texans’ need for electricity. An area the size of the United States receives more solar energy in less than 40 minutes than can be generated from all of the fossil fuels (oil, gas, etc.) used in the United States in one year. Texas has thousands of square miles that could be safely and efficiently used for solar power plants.

Photovoltaics offer consumers the ability to generate electricity in a clean, quiet, and reliable



RESIDENTIAL PV SYSTEM The solar panels on the roof produce electricity that travels through wires to the distribution panel on the side of the home.

required, such as emergency call boxes or school crosswalk signals, PV systems are often cost justified even when grid electricity is not very far away. When applications require larger amounts of electricity and are located away from existing power lines, photovoltaic systems can in many cases offer the least expensive, most viable option. In use today on streetlights, automatic gate openers and other low power tasks, photovoltaics are gaining popularity in Texas and around the world as their price declines and efficiency increases.



PHOTOVOLTAIC CELLS, MODULES AND ARRAYS *The building blocks of solar electricity are modular in nature, allowing great flexibility in applications.*

HOW IT WORKS

PV cells were developed in the 1950s as part of the space program. PV cells convert sunlight directly into electricity without creating any air or water pollution. PV cells are made of at least two layers of semiconductor material. One layer has a positive charge, the other negative. When light enters the cell, some of the photons from the light are absorbed by the semiconductor atoms, freeing electrons from the cell's negative layer to flow through an external circuit and back into the positive layer. This flow of electrons produces electric current.

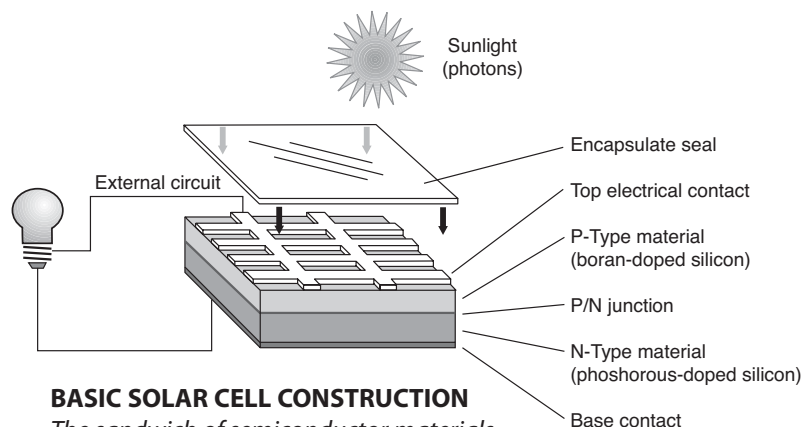
To increase their utility, many individual PV cells are connected together in a sealed, weatherproof package called a module. When two modules are wired together in series, their voltage is doubled while the

current stays constant. When two modules are wired in parallel, their current is doubled while the voltage stays constant. To achieve the desired voltage and current, modules are wired in series and parallel into what is called a PV array. Through a mixture of different series and parallel combinations, any desired voltage and current can be achieved. The flexibility of the modular PV system allows designers to create solar power systems that can meet a wide variety of electrical needs, no matter how large or small.

THE GRID: ON OR OFF?

Some homeowners in Texas are turning to PV as a clean, reliable, and infinitely renewable energy source even though it is often more expensive than power available from their electric utility. These homeowners can supplement their energy needs with electricity from their local utility when their PV system is not supplying enough energy (at nighttime and on cloudy days) and can export excess electricity back to their local utility when their PV system is generating more energy than is needed.

For locations that are “off the grid” — meaning they are far from, or do not use, existing power lines — PV systems can be used to power water pumps, electric fences or even an entire household.



BASIC SOLAR CELL CONSTRUCTION *The sandwich of semiconductor materials produce electricity directly from the sunlight without any moving parts.*

While PV systems may require a substantial investment, they can be cheaper than paying the costs associated with extending the electric utility grid. A consumer in Texas may be asked to pay anywhere from \$5,000 to \$30,000 per mile to extend power lines.

THE RIGHT EQUIPMENT FOR THE JOB

A grid-connected PV system will require a utility interactive DC to AC inverter. This device will convert the direct current (DC) electricity produced by the PV array into alternating current (AC) electricity typically required for household appliances such as radios, televisions and refrigerators. Utility interactive inverters also have built-in safety features required by electric utilities nationwide.

For an off-grid PV system, consumers must decide whether they want to use the direct current (DC) from the PVs or convert the power into alternating current (AC). Appliances and lights for AC are much more common and are generally cheaper, but the conversion of DC power into AC can consume up to 20 percent of all the power produced by the PV system.

To store electricity from PVs, batteries will be needed. The batteries used for PV systems are different from car batteries. The batteries best suited for use with PV systems are called secondary or deep cycle batteries. There are two types of deep cycle batteries: lead acid, which require the periodic addition of water, and captive electrolyte (or gelcell) batteries, which are maintenance free.

In addition, PV systems require proper wiring, switches and fuses for safety, controllers

to prevent the batteries from being overcharged or overly discharged, diodes to allow current to flow in the right direction, and grounding mechanisms to protect against lightning strikes.

LIGHT ENERGY

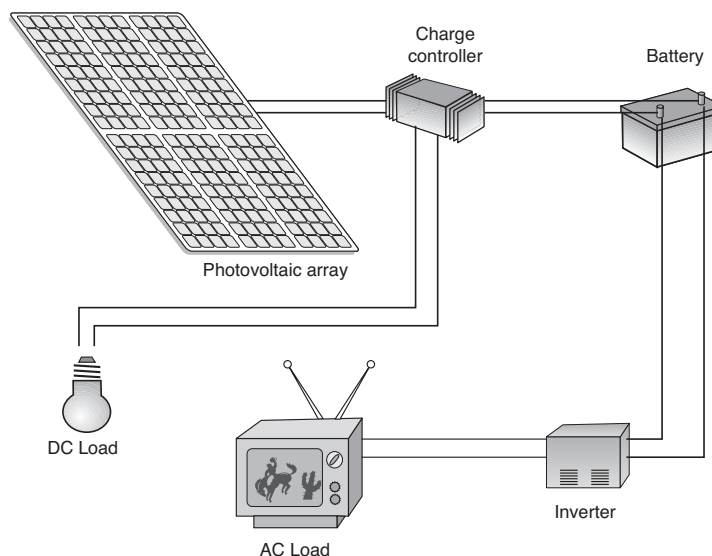
The color of light is related to its frequency. The frequency of light is related to its energy by this formula:

$$E = hf = \frac{hc}{\lambda}$$

In this formula, h is a constant, c is the speed of light, f is the frequency of the light, and λ is the wavelength of the light. The frequency of a color is directly proportional to its energy whereas the wavelength of a color is inversely proportional to its energy. Red has the least energy, and based on the formula above, a low frequency but relatively long wavelength; UV has a higher frequency and a relatively shorter wavelength.

The different colors of light can be arranged according to wavelength, frequency, or energy. From lowest energy to highest, the colors are red, orange, yellow, green, blue, violet, ultraviolet. That is, red has the least energy and ultraviolet has the highest energy. (A well known acronym to remember this order is ROY G BIV: red, orange, yellow, green, blue, indigo, violet.)

Sunlight contains a lot of infrared and ultraviolet as well as all other colors. Some people think heat is a different form of energy from light. Both are forms of electromagnetic radiation and both can provide energy for homes. Since most infrared and ultraviolet are blocked by Earth's atmosphere, solar energy, whether it is used to heat water or is converted to electricity in a PV cell, comes from the visible part of sunlight.



COMPONENTS OF A TYPICAL OFF-GRID PV SYSTEM Solar electricity can be used for many purposes, either directly, or by storing in batteries for use when the sun is not shining.

ORGANIZATIONS

American Solar Energy Society

2400 Central Ave., G-1
Boulder, CO 80301
(303) 443-3130
www.ases.org

Texas Solar Energy Society

P.O. Box 1447
Austin, TX 78767-1447
(800) 465-5049
e-mail: info@txses.org
www.txses.org
Solar goings on in Texas

Solar Energy International

P.O. Box 715
Carbondale, CO 81623-0715
(970) 963-8855
www.solarenergy.org
Info. on PV design, installation workshops

Solar Energy Industries Association

805 15th Street, NW Suite 510
Washington, DC 20005
(202) 6820556
<http://www.seia.org/>
Comprehensive list of PV manufacturers

Texas Renewable Energy Industries Association

P.O. Box 16469
Austin, TX 78761
(512) 345-5446
www.treia.org/
go to search our members for a list of
PV Suppliers and installers

RESOURCES

FREE TEXAS RENEWABLE ENERGY INFORMATION

For more information on how you can put Texas' abundant renewable energy resources to use in your home or business, visit our website at www.InfinitePower.org or call us at 1-800-531-5441 ext 31796. Ask about our free Teacher Resource Guides and CD available to teachers and home schoolers.

ON THE WORLD WIDE WEB:

The U. S. Department of Energy - Energy Efficiency and Renewable Energy. This site has a comprehensive list of related web sites.
<http://www.eere.energy.gov/AB/>

Florida Solar Energy Center. Information on photovoltaics, batteries, alternatives buildings systems, solar heaters. FSEC offers training courses such as, "Installation of Grid-Connected Photovoltaic Systems." www.fsec.ucf.edu

Real Goods. Site offers introductory explanations of solar technologies, You can buy a wide variety of solar goods, PV modules, compact fluorescent bulbs and other gear. A worthy stop for anyone shopping for solar-powered or energy efficient items. www.realgoods.com

U. S. DOE Solar Energy Technologies Program. This site has a much more detailed fact sheet on PV basics.
http://www1.eere.energy.gov/solar/pv_basics.html

U. S. Department of Energy - Energy Efficiency and Renewable Energy Information Resources Catalog. Our new online catalog offers quick and easy access to a growing number of publications, videos, software and other information products across EERE. <http://www.eere.energy.gov/catalog/>

Sandia National Laboratory Photovoltaic Program. This site offers descriptions of a variety of PV systems. This rich site also includes system sizing worksheets, PV codes and standards, and PV economics.
www.sandia.gov/pv/

BOOK:

Just add Sunshine, Solar Electricity Will Set You Free. J. Michael Mooney, ARC Press of Cane Hill, 1997. A self study guidebook on the exciting world of solar electricity. Detailed examples of PV systems to power both large and small dwellings are included. (Available at 1-800-340-8242)



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State Energy Conservation Office

111 East 17th Street, Room 1114
Austin, Texas 78774
Ph. 800.531.5441 ext 31796
www.InfinitePower.org

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